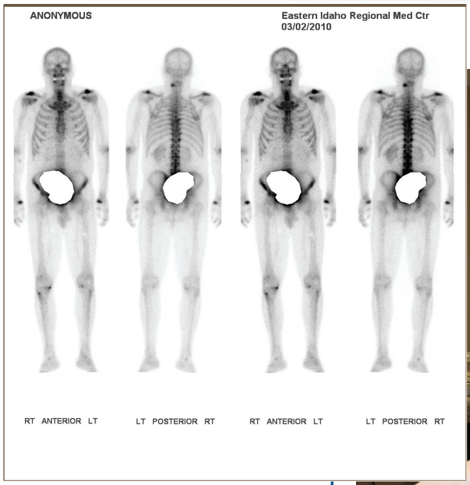

Technetium images, like the bone scan above, are created by injecting a radioisotope and scanning the patient's body with a gamma reader, like the one at right.

Accelerator Generation and Thermal Separation of Technetium-99m

Idaho National Laboratory (INL) researchers have developed an integrated process to produce technetium-99m using a linear electron accelerator. The key to the process is an advanced thermal separation technique that exploits the difference in vaporization pressure between the parent isotope of technetium-99m, molybdenum-99, and the daughter isotope.

Technetium-99m is the top-of-the line radioisotope for imaging internal structures. It was the diagnostic tool of choice for more than 30 million diagnostic and imaging procedures last year in 10,000 hospitals worldwide. Technetium-99 is a metastable isotope with a half-life of only six hours. That's long enough for it to be chemically prepared and injected into a patient, where it binds with chemicals used in body processes and migrates to the part of the body doctors need to see. This isotope is used in 90% of nuclear-medicine procedures and has, since its introduction 53 years ago, replaced exploratory surgery as a means of understanding the body's inner workings.

A Life-Threatening Shortage

As of 2010, the entire world's supply of molybdenum-99 is produced in four reactors. Once the source of 30% of the worlds technetium-99m, Canada's National Research Universal (NRU) reactor currently is shut down for work to correct reactor vessel leaks. Already two deadlines have passed without its returning to production. The reactors presently equipped to manufacture this valuable radioisotope have an average age of 48 years—1962 Fairlanes in a Prius world.

The shortage has real costs now: heart and bone scans are being delayed or not performed at all. Some imaging procedures are performed using alternate, more expensive isotopes, but some procedures have no alternative isotopes. In some nations, routine bone scans for cancer patients have decreased as much as 70%. Medicine is literally being practiced as it was before the development of advanced imaging techniques, reversing 30 years of progress in diagnostics.

A Better Idea

Technetium production from molybdenum-100 using an accelerator has long been recognized as a less-expensive alternative than production from uranium-235 in a nuclear reactor. Historically, the problem has been finding a way to separate the resulting technetium. Accelerator-produced technetium-99m has low specific activity and, thus, could not be separated from its parent in useful concentrations. Scientists and engineers at the INL found an alternative to the ion chromatography currently used to separate technetium from molybdenum: thermal separation. In this technique, the target is dissolved in acid, evaporated to dryness, and calcined to MoO_3. The MoO_3 precipitates as fine crystalline needles that readily release the technetium as technetium oxide Tc_2O_7 vapors in a stream of oxygen at moderate temperatures where oxides of molybdenum and niobium isotopes – the other byproducts in the target – are not volatile. The Tc_2O_7 is condensed at ambient temperature in a small exit tube, from which it is dissolved in isotonic saline solution for the radiopharmaceutical product. All of this work can be performed in the same small building in which the accelerator resides, so near to radiopharmacies that shipments of the new Tc generators could be safely delivered in the trunks of passenger cars. The accelerator used to produce the Molybdenum-99 is small. It would sit in the basement of a facility with a floor space of about 1600 ft^2, roughly two-thirds the size of the average American home, and this facility would not only produce the radioisotope, but would house everything necessary to perform separation.

Technetium can be generated using an accelerator no larger than a steamer trunk, obviating the need for a nuclear reactor and its support system.

Advantages That Go Beyond Cost

When molybdenum-99 is produced in a nuclear reactor, it is produced from a target of highly enriched uranium, which is weapons-grade material and highly fissile. The United States is the sole supplier of uranium-235 targets for medical isotope production, and supplying the world requires a significant amount. Naturally, people who worry about proliferation and terrorism would like to see less HEU transported around the world or stored at research reactors.

AGATS production from molybdenum-100 takes place in a large number of small facilities, each capable of producing daily doses sufficient to serve the demand generated by around 10 million people. Thus, roughly 30 AGATS facilities (each costing $5 million to build and $1 million to operate annually) would meet American demand. In other words, at current market prices for technetium-99m, these units would operate profitably and without government subsidy, producing isotopes with the same purity at roughly half the current cost, while eliminating both very real proliferation concerns and life-threatening shortages caused by dependence on a limited number of isotope-producing research reactors.

AGATS, an integrated production system, is modular and distributed, not subject to the single-point production failures that plague the current system and have led to widespread shortages. The advantages to such a system include:

- No need for a nuclear reactor
- No requirement for fissile material at any point in the production process
- Reduced risk of transportation accident or terrorist diversion
- No radioactive waste stream
- Improved security of supply thanks to the distributed production to many small sites
- Proximity of production to end users
- Capital costs of production facility at between two and three orders of magnitude less than alternatives
- Much less arduous permitting for an accelerator compared to a nuclear reactor
- Ease of transportation of final product to radiopharmacies

Final product cost is estimated at 1/2 of price using current production methods, which are themselves heavily subsidized by government construction of reactors.

For more information

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